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أسم المادة : (قوى كهربية) ع

قســـــم: {ميكانيكا}

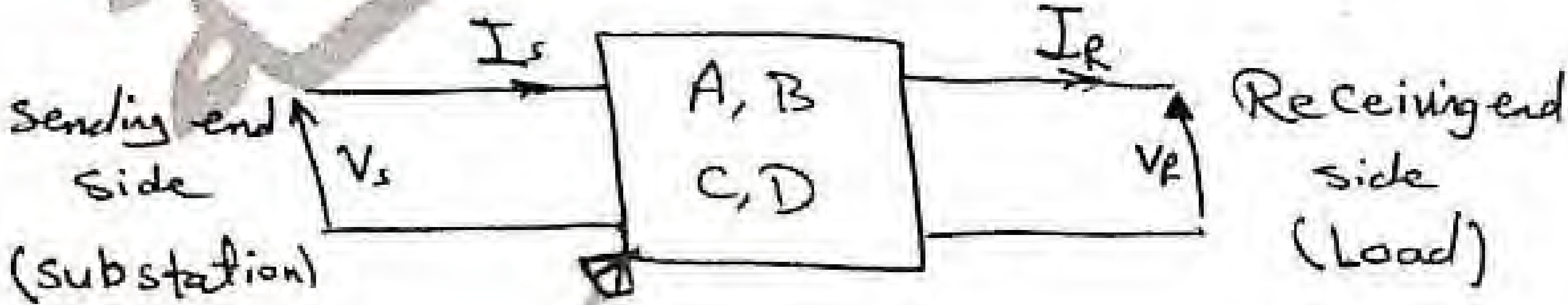
الفرقـــــة : {الثانية}

عنوان الدرس : Transmission line Parameters

2

Transmission Line Parameters

* Introduction:



$$V_{S_{ph}} = A V_{R_{ph}} + B I_R$$

$$I_{S_{ph}} = C V_{R_{ph}} + D I_R$$

In matrix form

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_{R_{ph}} \\ I_R \end{bmatrix}$$

If we need to calculate $V_{R_{ph}}$, I_R

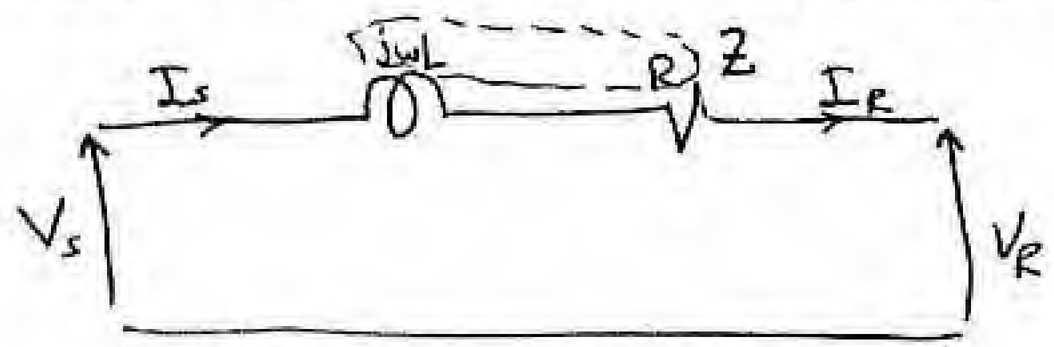
$$\begin{bmatrix} V_{R_{ph}} \\ I_R \end{bmatrix} = \frac{1}{\underbrace{AD - BC}_{=1}} \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_{s_{ph}} \\ I_s \end{bmatrix}$$

* Transmission Line Models:-

① Short transmission Line:-

(Length $\leq$ 80 km)

The transmission Line will represented as follow:-



Using KVL & KCL :-

$$V_{s_{ph}} = V_{R_{ph}} + (R + j\omega L) I_R$$

$$V_{s_{ph}} = V_{R_{ph}} + Z I_R \longrightarrow ①$$

$$I_s = I_R \longrightarrow ②$$

from ① & ②

$A = 1$, $C = 0$

$B = Z = R + j\omega L$, $D = 1$

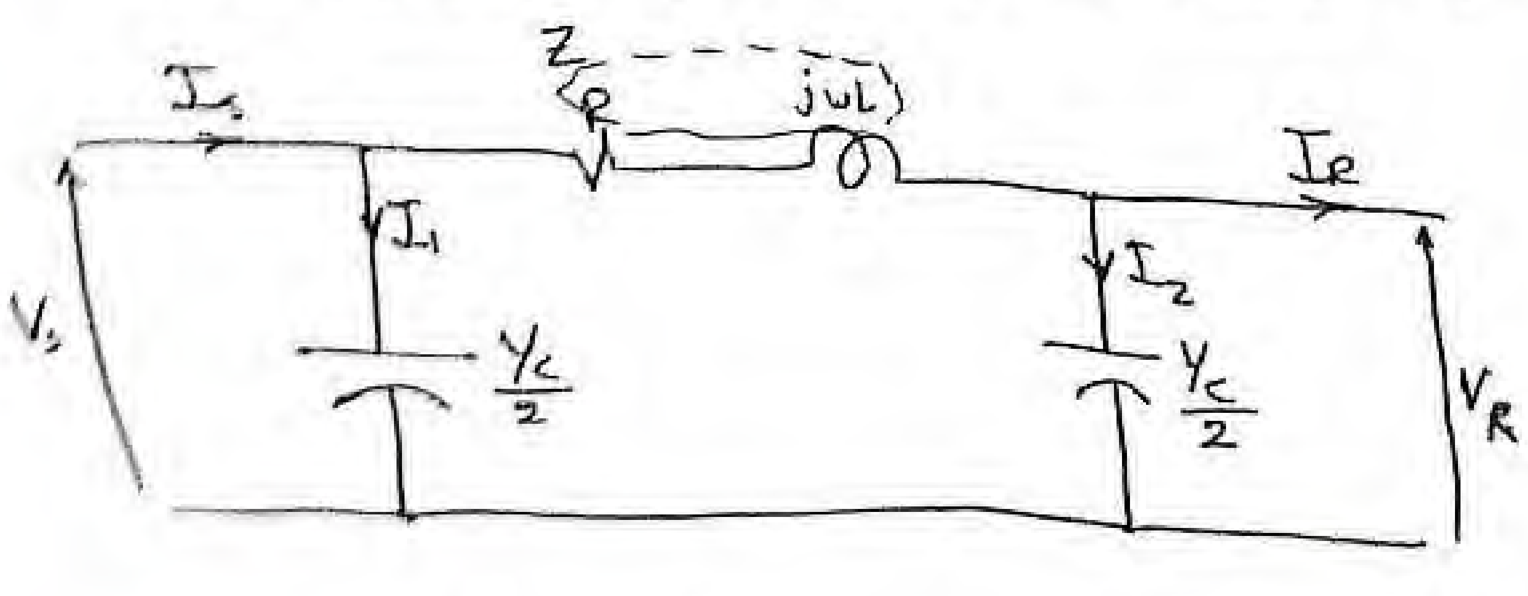
Note That:- $\omega = 2\pi f$

② Medium transmission Line:

($80km < L \leq 240$ km)

Using π Model

The transmission Line will represented as follow:-



where :- $Y_c = j\omega C$

Using KVL & KCL

$$\rightarrow V_s = V_R + Z(I_R + I_2)$$

$$= V_R + Z\left(I_R + V_R \times \frac{Y_c}{2}\right)$$

$$= V_R + Z I_R + \frac{Z Y_c}{2} V_R$$

$$\boxed{\therefore V_s = \left[1 + \frac{Z Y_c}{2}\right] V_R + Z I_R} \longrightarrow (1)$$

$$\rightarrow I_s = I_1 + I_R + I_2$$

$$= V_s \times \frac{Y_c}{2} + I_R + V_R \times \frac{Y_c}{2}$$

substitute from (1)

$$\therefore I_s = \frac{Y_c}{2}\left[\left(1 + \frac{Z Y_c}{2}\right) V_R + Z I_R\right] + I_R + \frac{Y_c}{2} V_R$$

$$= \frac{Y_c}{2}\left(1 + \frac{Z Y_c}{2}\right) V_R + \frac{Z Y_c}{2} I_R + I_R + \frac{Y_c}{2} V_R$$

$$\boxed{\therefore I_s = Y_c\left(1 + \frac{Z Y_c}{4}\right) V_R + \left(1 + \frac{Z Y_c}{2}\right) I_R} \longrightarrow (2)$$

From 1 & 2

$$A = D = 1 + \frac{ZY_c}{2}$$

$$B = Z = R + j\omega L$$

$$C = Y_c\left(1 + \frac{ZY_c}{4}\right)$$

* V.I.P :-

→ $V_L = \sqrt{3}\, V_{ph}$

→ Power factor :- (P.f)

$P.f = \cos\phi$

where $\phi = \theta_V - \theta_i \longrightarrow$ Lag P.f

$\phi = \theta_i - \theta_V \longrightarrow$ Lead P.f

→ Active Power :- (P)

$P = 3 V_{ph} I_{ph} * P.f$ (Watt)

$= \sqrt{3}\, V_L I_L \cdot P.f$

Note1. P :- is real Quantity

$$S = 3 V_{ph} I_{ph}^{*}$$

$$= \sqrt{3} V_L I_L^{*} \quad (V.A) \leftarrow \text{Volt. ampere}$$

Note:- S:- is Complex Quantity

$$|S| = \sqrt{3} |V_L| \, |I_L|$$

$$= 3 \, |V_{ph}| \, |I_{ph}|$$

$$|S| = \frac{P}{\cos \phi}$$

→ Reactive Power:- (Q)

$$Q = 3 V_{ph} I_{ph} \sin \phi$$

$$= \sqrt{3} V_L I_L \sin \phi \quad (VAR)$$

or $Q = \sqrt{S^2 - P^2}$

Q is real Quantity

→ Efficiency:- (η)

$$\eta = \frac{P_R}{P_S} \times 100\%$$

→ Voltage regulation: (V.R)

$$\% V.R = \frac{V_{n.L} - V_{FL}}{V_{FL}} \times 100\%$$

Where:
$V_{FL} = V_R$ (at full Load)

$V_{n.L} = V_R$ (at No Load)

Recall $V_s = A V_R + B I_R$

at No load means $I_R = 0$

$$\therefore \underset{\text{at no load}}{V_R} = \frac{V_s}{|A|}$$

$$\boxed{\therefore \% V.R = \frac{\frac{|V_s|}{|A|} - |V_R|}{|V_R|} \times 100\%}$$

* Steps of Solution:-

1. Define The Model of T.L [short or Medium]
2. Calculate $Z = R + j\omega L$

   $Y = j\omega C$
3. find A, B, C & D Parameters
4. Choose reference Value:-

   Ex:- if $V_{R_{ph}} = 220kV \longrightarrow V_{R_{ph}} = 220kV\angle 0$
5. find I_R using The given data:-

   Ex:- if P_R is given

   $\therefore P_R = 3 V_{R_{ph}} I_R \times P.f$
6. find V_s, I_s

   $V_s = A V_R + B I_R$

   $I_s = C V_R + D I_R$
7. Now we Can Calculate P_s, Q_s, S_s, $P.f_s$

   η, $VR\%$

Faculty of engineering

Electrical engineering department

Assignment (1)

Transmission line parameters

1- A three phase short transmission line is 40 Km long. The line has a per phase series resistance of 0.15Ω per Km and per phase series inductance of 1.3263mH per Km. Determine the sending end voltage, the sending end apparent power, voltage regulationand the transmission efficiency when the line delivers:
   a- 381 MVA, 0.8 lagging power factor at 220 KV.
   b- 120 MVA, unity power factor at 64KV.
2- A three phase transmission line is 130 Km long. The line has a per phase series resistance of 0.036 Ω per Km, per phase series inductance of 0.8mH per Km and per phase shunt capacitance of 0.0112 μF per Km. the receiving end load is 270 MVA with 0.8 lagging power factor at 325 KV. Use medium line model to determine the sending end voltage and the sending end apparent power.
3- A 230-KV three phase transmission line has a per phase series impedance of z=.05+j45 Ω per Km and a per phase shunt admittance of y=j3.4μs per Km. the line is 80 Km long. Using the nominal π –model, determine:
   a- The transmission line ABCD constants. Then find the sending end voltage and current, voltage regulation, the sending end power and the transmission efficiency when the line delivers:
   b- 200 MVA, 0.8 lagging power factor at 220 KV.
   c- 306 MW, unity power factor at 220 KV.
4- A 66 KV three phase short transmission linehas a per phase series impedance of 5 ang(75)Ω. Determine the receiving end voltage, current, power factor, voltage regulation and the transmission efficiency when the sending end is:
   50 MVA, 0.8 lagging power factor at 66 KV.
5- A 66-KV three phase medium transmission line has a per phase series impedance of z=15 ang(75) Ω and a per phase shunt admittance of y=j0.001S. Determine the receiving end voltage, current, power factor, voltage regulation and the transmission efficiency when the sending end is:
   50 MVA, 0.8 lagging power factor at 66 KV.

EX1-

40 km, 220 kV, $R = .15\ \Omega/Km$

$L = 1.3263\ mH/Km$

find:- V_s, S_s, $V.R\%$, η

for 381 MVA Load at .8 Lag Pf & 220 kV.

Sol

→ 40 km → short T.L

$\rightarrow Z = (R + j\omega L)$

$= [.15 + j2\pi \times 60 \times 1.3263 \times 10^{-3}] \times 40$

$$\boxed{Z = 6 + j20\ \Omega}$$

→ for short T.L

$A = D = 1$

$B = Z = 6 + j20$

$C = 0$

→ Reference Value is

$V_{R_L} = 220kV$

$\therefore V_{R_{ph}} = \frac{220}{\sqrt{3}} \angle 0$ KV

→ $|S_R| = 3 V_{R_{ph}} I_{R_{ph}}$

$381 \times 10^6 = 3 \times \frac{220 \times 10^3}{\sqrt{3}} \times I_R$

$\therefore I_R = 1000 A$ [magnitude]

To calculate angle of I_R

$\because Pf = .8$ Lag

$\therefore .8 = \cos(\theta_{V_R} - \theta_{I_R})$

$.8 = \cos(0 - \theta_{I_R})$

$\therefore \theta_{I_R} = -36.87°$

$$\boxed{\therefore I_R = 1000 \angle -36.87° \text{ A}}$$

$\rightarrow V_{s_{ph}} = A V_{R_{ph}} + B I_R$

$= 1 \times \dfrac{220 \times 10^3}{\sqrt{3}} \angle 0 + (6 + j20) \times 1000 \angle -36.87^\circ$

$\boxed{\therefore V_{s_{ph}} = 144.33 \angle 4.93^\circ \text{ kV}}$

$\therefore V_{s_L} = \sqrt{3}\, V_{R_{ph}} = 250 \angle 4.93 + 30^\circ \text{ kV}$

علشان dp

$\boxed{\therefore V_{sL} = 250 \angle 34.93^\circ \text{ kV}}$

$\rightarrow I_s = I_R = 1000 \angle -36.87^\circ$

$\rightarrow P.f_s = \cos(\theta_{V_s} - \theta_{I_s}) = \cos[4.93 - (-36.87)]$

$\boxed{P.f_s = .75 \text{ Lag}}$

$\rightarrow P_s = 3 V_{s_{ph}} \times I_{s_{ph}} \times P.f$

$= 3 \times 144.33 \times 10^3 \times 1000 \times .75$

$\boxed{P_s = 324.8 \text{M watt}}$

$\rightarrow S_s = 3 V_{sph} I_s^*$

$= 3 * 144.33 * 10^3 \angle 4.93 * 1000 \angle -36.87$

cur. lag

$$\boxed{\therefore S_s = 433 \angle 41.8 \text{ MVA}}$$

$\rightarrow \% V.R = \dfrac{\frac{|V_s|}{|A|} - |V_R|}{|V_R|} * 100\%$

$\% V.R = \dfrac{\frac{250}{1} - 220}{220} * 100\% = 13.6\%$

$\rightarrow \eta = \dfrac{P_R}{P_S} * 100\% = \dfrac{S_R * P.f}{P_S} * 100\%$

$= \dfrac{381 * .8}{324.8} * 100\%$

$$\boxed{\therefore \eta = 93.85\%}$$

Ex:-

Medium T.L, R = .036 Ω/km

L = .8 mH/km, C = .0112 μf/km find

V, S at sending end of The Line for

270 MVA Load at .8 Lag P.f, 325 KV

if The Length of T.L is 130 km

Soln

$$\rightarrow Z = (R + j\omega L) = (.036 + j \times 2\pi \times 60 \times .8 \times 10^{-3}) \times 130$$

$$\boxed{Z = 4.68 + j\,39.2\ \Omega}$$

$$Y_c = j\omega C = j \times 2\pi \times 60 \times .0112 \times 10^{-6} \times 130$$

$$\boxed{Y_c = j\,.549 \times 10^{-3}\ \mho}$$

$$\rightarrow A = D = 1 + \frac{ZY}{2} = 1 + \frac{(4.68 + j\,39.2) \times j\,.549 \times 10^{-3}}{2}$$

$$= .989 + j\,.00128 = .989 \angle .07$$

$$B = Z = 4.68 + j\,39.2$$

$$C = Y_c\left(1 + \frac{ZY_c}{4}\right) = 5.46 \times 10^{-4} \angle 90.04$$

→ Let $V_{RL} = 325\ kV$

$\therefore V_{Rph} = \frac{325}{\sqrt{3}} \angle 0\ kV = 187.6 \angle 0\ kV$

→ $|S_R| = 3 V_{Rph} I_{Rph}$

$270 \times 10^6 = 3 \times 187.6 \times 10^3 \times I_R$

$\therefore |I_R| = 480\ A$

$\because Pf_R = .8$ Lag

$\therefore .8 = \cos(\theta_{V_R} - \theta_{I_R})$

$\therefore \theta_{I_R} = -36.87°$

$$\boxed{\therefore I_R = 480 \angle -36.87°\ A}$$

$\rightarrow V_{s_{ph}} = A V_{R_{ph}} + B I_R$

$= .989 \angle 0.7 \times 187.6 \times 10^3 \angle 0 + [(4.68 + j\,39.2) \times 480 \angle -36.87^\circ]$

$$\boxed{\therefore V_{s_{ph}} = 199.16 \angle 4.02^\circ \text{ kV}}$$

$\therefore V_{s_L} = 345 \angle 34.02 \text{ kV}$

$\rightarrow I_s = C V_R + D I_R$

$= 5.46 \times 10^{-4} \angle 90.04 \times 187.6 \times 10^3 \angle 0 + [.989 \angle 0.7 \times 480 \angle -36.87^\circ]$

$$\boxed{I_s = 421.5 \angle -25.58 \text{ A}}$$

$\rightarrow S_s = 3 V_{s_{ph}} \times I_{s_{ph}}^*$

$= 3 \times 199.16 \times 10^3 \angle 4.02 \times 421.5 \angle 25.58$

$$\boxed{S_s' = 251.84 \angle 29.6^\circ \text{ MVA}}$$

Ex:-

66kV, short T.L, $Z = 5\angle 75^\circ\ \Omega$

$S_s = 50MVA$, $Pf = .8$ Lag

Find:- V_R, I_R, P.f, V.R%, η

Soln

$\rightarrow A = D = 1 \qquad , C = 0$

$B = Z = 5\angle 75^\circ\ \Omega$

$\rightarrow V_{sph} = \frac{66}{\sqrt{3}}\angle 0\ kV$

$\rightarrow |S_s| = 3\ V_{sph}\ I_{sph}$

$50 \times 10^6 = 3 \times \frac{66}{\sqrt{3}} \times 10^3 \times I_{sph}$

$|I_s| = 437.386\ A$

$\because Pf_s = .8$ Lag $= \cos(\theta_{V_s} - \theta_{I_s})$

$\therefore \theta_{I_s} = -36.87^\circ$

$$\boxed{\therefore I_s = 437.386\angle -36.87^\circ\ A}$$

$\rightarrow I_s = I_R = 437.386 \angle -36.87^\circ$ A

$\rightarrow V_{s_{ph}} = A V_{R_{ph}} + B I_R$

$$\frac{66}{\sqrt{3}} \times 10^3 \angle 0 = 1 \times V_{R_{ph}} + 5 \angle 75 \times 437.386 \angle -36.87$$

$$\boxed{\therefore V_{R_{ph}} = 36.409 \angle -2.125^\circ \text{ kV}}$$

$$V_{RL} = 63.063 \angle 27.875 \text{ kV}$$

$\rightarrow Pf_R = \cos(\theta_{V_R} - \theta_{I_R})$

$$= \cos(-2.125 + 36.87)$$

$$\boxed{Pf_R = .82 \text{ Lag}}$$

$\rightarrow P_R = 3 V_{R_{ph}} I_R \times Pf$

$$= 3 \times 36.409 \times 10^3 \times 437.386 \times .82$$

$$\boxed{P_R = 39.256 \text{ MW}}$$

$$\rightarrow \therefore N.R = \frac{\frac{|V_s|}{|A|} - V_R}{V_R} \times 100\%$$

$$= \frac{\frac{66}{1} - 63.063}{63.063} \times 100\%$$

$$\boxed{\therefore N.R = 4.66\%}$$

$$\rightarrow \eta = \frac{P_R}{P_s} \times 100\%$$

$$= \frac{39.256}{50 \angle -8} \times 100\%$$

$$\boxed{\therefore \eta = 98.15\%}$$

Ex1-

66 kV, $Z = 15\angle 75^\circ$, $Y = .001\angle 90^\circ$ S

Medium T.L, $S_s = 50$ MVA, Pf $= .8$ Lag

find:- V_R, I_R, Pf, V.R %, η

Sol

$$\rightarrow A = D = 1 + \frac{ZY}{2} = 1 + \frac{15\angle 75 \times .001\angle 90}{2}$$

$$= .993\angle 0.112$$

$$B = Z = 15\angle 75^\circ \ \Omega$$

$$C = Y\left(1 + \frac{ZY}{4}\right) = .001\angle 90\left(1 + \frac{15\angle 75 \times .001\angle 90}{4}\right)$$

$$= 9.964 \times 10^{-4}\angle 90.1^\circ$$

$$\rightarrow V_{s_{ph}} = \frac{66}{\sqrt{3}} \times 10^3 \angle 0 \text{ kV}$$

$$\rightarrow |S_s| = 3 V_{s_{ph}} I_{s_{ph}}$$

$$50 \times 10^6 = 3 \times \frac{66000}{\sqrt{3}} \times I_{s_{ph}}$$

$$\boxed{I_{s_{ph}} = 437.386 A}$$

$\because Pf_s = .8 \text{ Lag} = \cos(\theta_{V_s} - \theta_{I_s})$

$\therefore \theta_{I_s} = -36.87^\circ$

$$\boxed{\therefore I_s = 437.386 \angle -36.87^\circ \text{ A}}$$

$$\rightarrow \begin{bmatrix} V_{R_{ph}} \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_{s_{ph}} \\ I_s \end{bmatrix}$$

$\therefore V_{R_{ph}} = D V_{s_{ph}} - B I_s$

$= .993 \angle .112 \cdot \frac{66000}{\sqrt{3}} \angle 0 - 15 \angle 75 \cdot 437.386 \angle -36.9$

$$\boxed{V_{s_{ph}} = 32.909 \angle -6.94 \text{ kV}}$$

$V_{s_L} = 57 \angle 23.06 \text{ kV}$

$I_R = -C V_{s_{ph}} + A I_s$

$$\boxed{I_R = 457.978 \angle -40.56^\circ \text{ A}}$$

& Continue as before

* Lecture example 1.

A Three phase 50 HZ transmission Line has a series resistance of 0.074 Ω/km, a series inductance of 0.12 μH/km, and The shunt Capacitance of 9.577 nf/km. The line is 150 km Long. Find The equivalent Circuit element. use The nominal π Model. if The Line is open circuited and energized to a voltage Level of 230 kV as measured at sending end, find voltage at the open end.

— Sol —

$$\rightarrow Z = (.074 + j\, 2\pi \times 50 \times .12 \times 10^{-6}) \times 150 = 11.1 + j5.65 \times 10^{-3}\ \Omega$$

$$Y = j\omega c = (j 2\pi \times 50 \times 9.577 \times 10^{-7}) \times 150 = j4.5 \times 10^{-4}$$

$$\rightarrow A = D = 1 + \frac{ZY}{2} = 1 \angle .144$$

$$B = Z = 11.1 + j\,5.65 \times 10^{-3}$$

$$C = Y\left(1 + \frac{ZY}{4}\right) = 4.5 \times 10^{-4} \angle 90.1$$

$$\rightarrow V_{s_{ph}} = \frac{230000}{\sqrt{3}} \angle 0$$

لم يعطى data لإيجاد ال I_s وستو تعتبر انتا نطبق المعادلة دى

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$$

$$\therefore V_R = D V_s - B I_s$$

$$I_R = -C V_s + A I_s$$

ولكن كده عندي 3 مجاهيل وبالتالي لا يمكن حلها

- صوتال من المسائل

The Line is open circuited

i.e. $I_R = 0$

وبالتالي أنا مش لازم أجيب Matrix inverse أصلاً

$$V_s = A V_R + B \cancel{I_R} \xrightarrow{} 0$$

$$\therefore V_R = \frac{V_s}{A} = \checkmark$$

→ If given data of receiving end (أكتر حاجة) and required sending end:

$$\therefore V_s = A V_R + B I_R \;, \; I_s = C V_R + D I_R$$

→ If given data of sending end & required receiving end

→ (a) <u>short T.L.</u>:

$$I_s = I_R$$

$$\therefore V_s = A V_R + B I_R$$

(b) Medium T.L & Line is open circuited

given V_s only

$\therefore I_R = 0$

$\therefore V_s = A V_R$

$I_s = C V_R$

(c) Medium T.L , V_s , I_s are given

Here we must apply matrix inverse

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$$

وبالتالي مش محتاج أطبق الـ Inverse إلا في هذه الحالة فقط